An Update on Measuring $\mathrm{B}(\pi^0 \to e^+e^-\gamma)$ using $K_L \to 3\pi^0$

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Outline

- Current PDG Value
- Sample & Statistics
- Systematics & Strategies

PDG Average for π^0 Dalitz Decay

$\frac{\Gamma(\gamma e^+ e^-)}{\Gamma(2\gamma)} = (1.213 \pm .030)\%$

From

$(1.25 \pm .04)\%$ Schardt 1981, $\pi^- p \to n\pi^0$

$(1.166 \pm .047)\%$ Samios 1961, 3071 events, $\pi^- p \to n\pi^0$

$(1.17 \pm .15)\%$ Budagov 1960, 27 events

No measurements of π^0 Dalitz decay BR for $\sim$ 25 years. The 2.5% uncertainty on the current number affects many other measurements. KTeV has plenty of events to reduce the uncertainty, and this will have a broad impact on other measurements.

Sample & Statistics

- Signal: $K_L \to 3\pi^0$, where one $\pi^0 \to e^+e^-\gamma$
- Normalization: $K_L \to 3\pi^0$ with $\pi^0 \to \gamma\gamma$
- Ideally, use trigger 6 for both, but too restrictive (requires exactly 6 clusters at L3)

Trigger 6 for $K_L \to 3\pi^0$ events, for normalization (prescale by 10)

Trigger 14 for Dalitz decay events

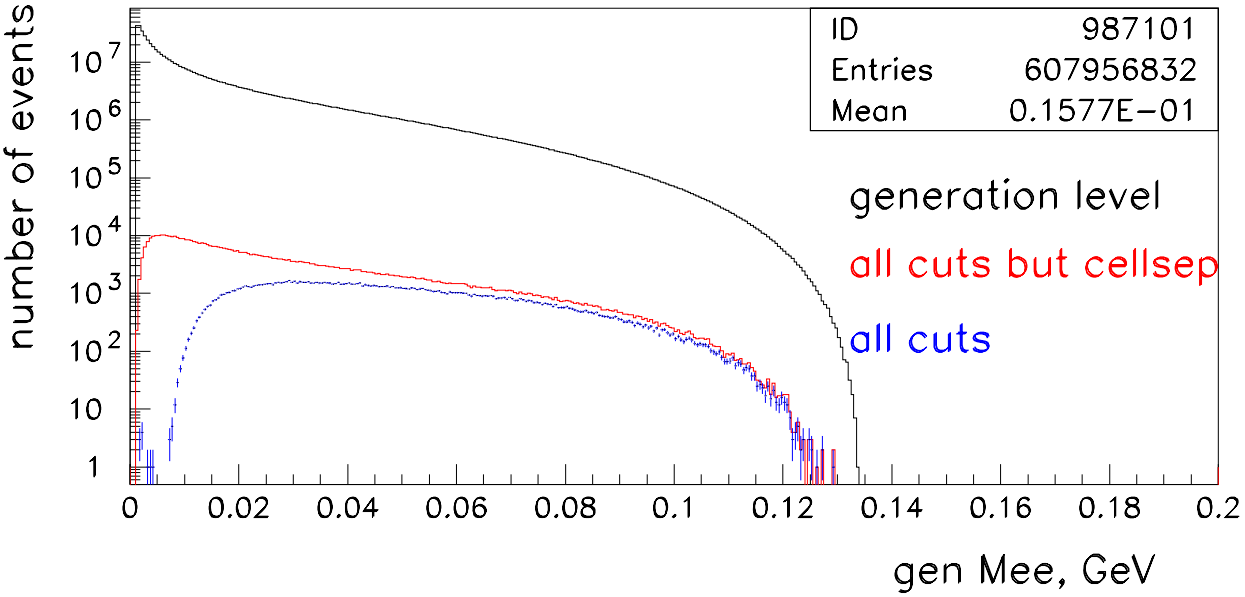
Trigger 14: combination charged & neutral trigger; similar to trigger 1 (charged mode trigger for ϵ'); requires 7 or more HCC, has HA veto

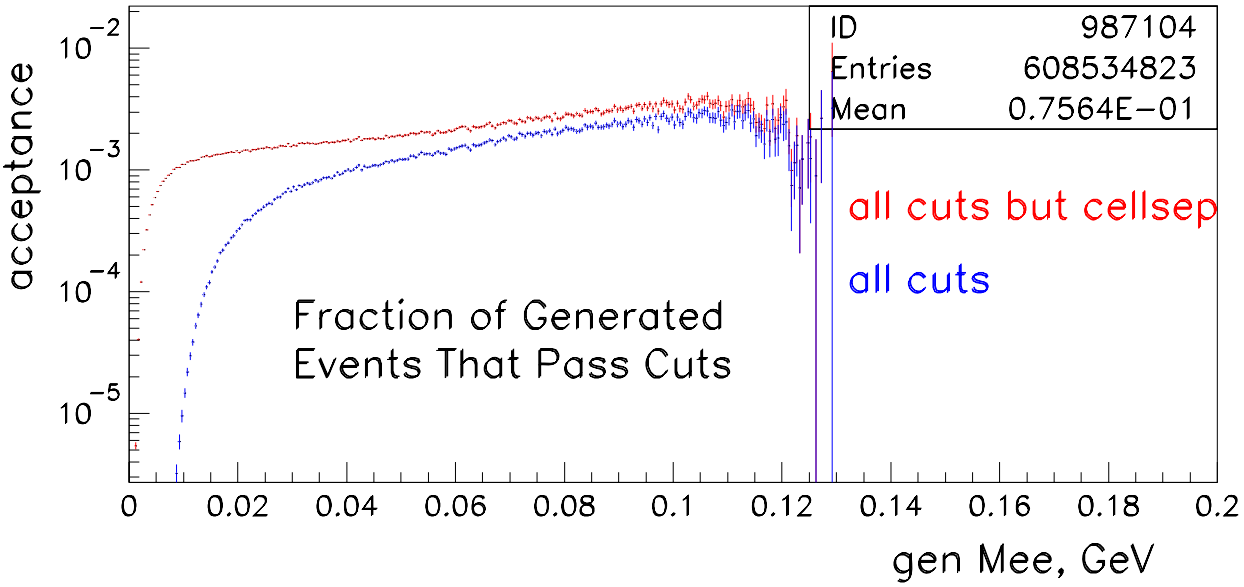
Main criteria for event selection:

- kaon mass: [0.490, 0.505] GeV/c^2
- kaon z: [123.0, 158.0] m
- kaon energy: [40.0, 160.0] GeV
- min cluster energy: 3.0 GeV
- NEW: cell separation cut of 3

Imposing a cellsep cut is result of needing to know tracking efficiency very well; tracking efficiency was studied for well-separated tracks for V_{us}, so cellsep cut allows us to use results of those studies. However, cut reduces event sample by factor of ~3, and the statistical uncertainty will be ~0.35%.

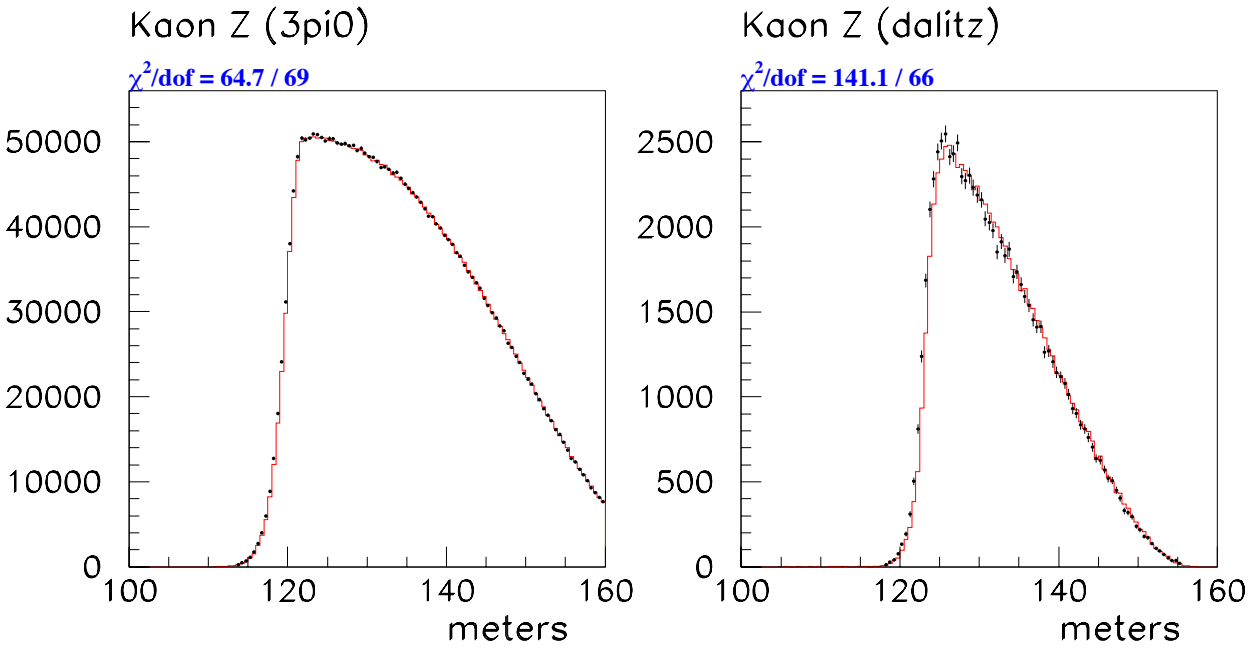
Cell Separation Cut and e^+e^- Mass

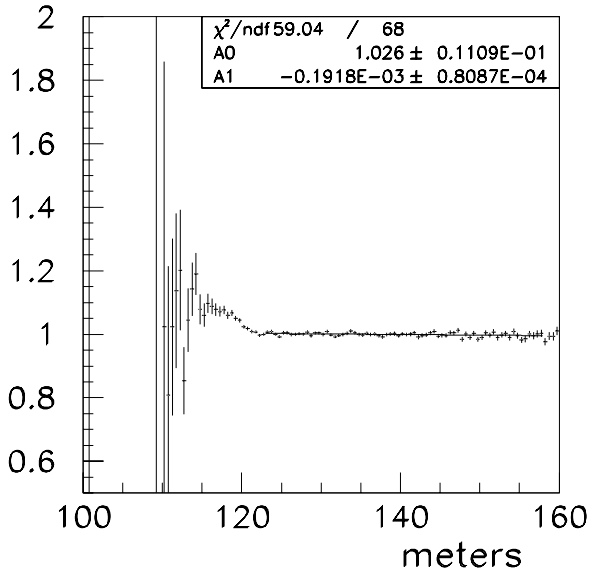


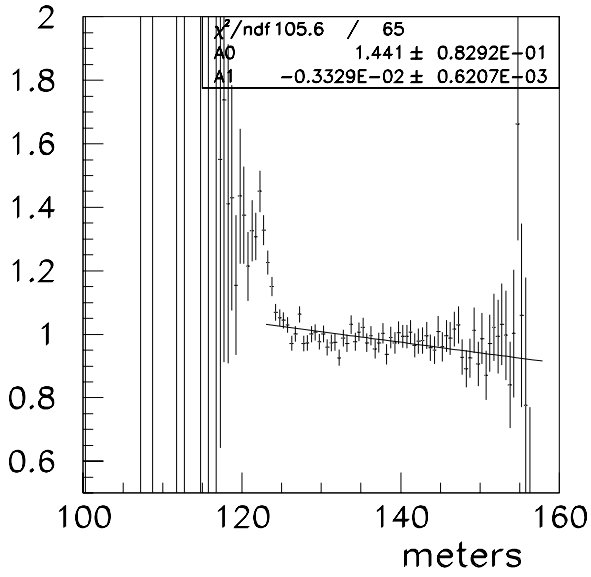


Also, note that e^+e^- mass resolution is $\sim$ 1 MeV.

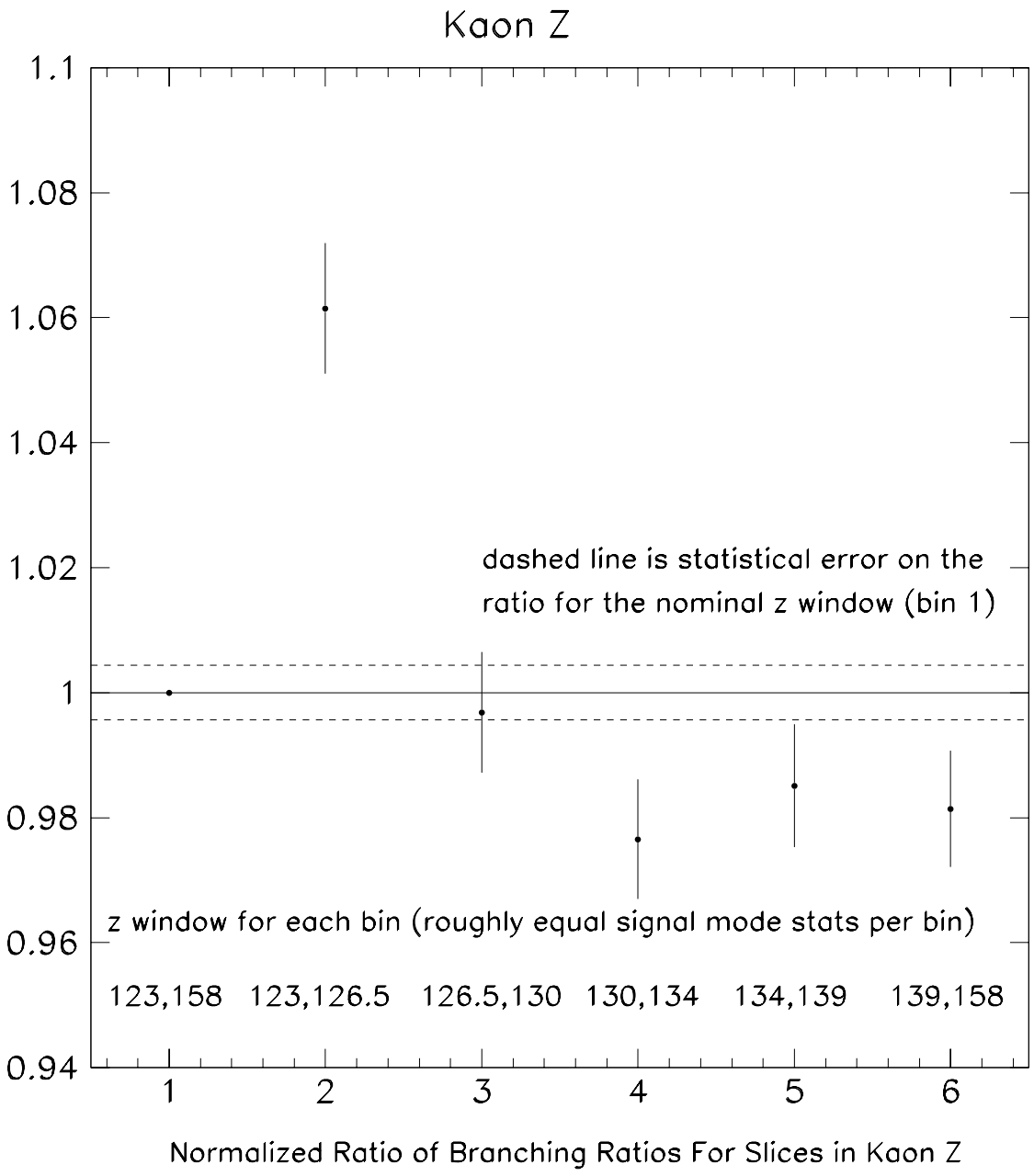
Systematics & Strategies: Cut Variations

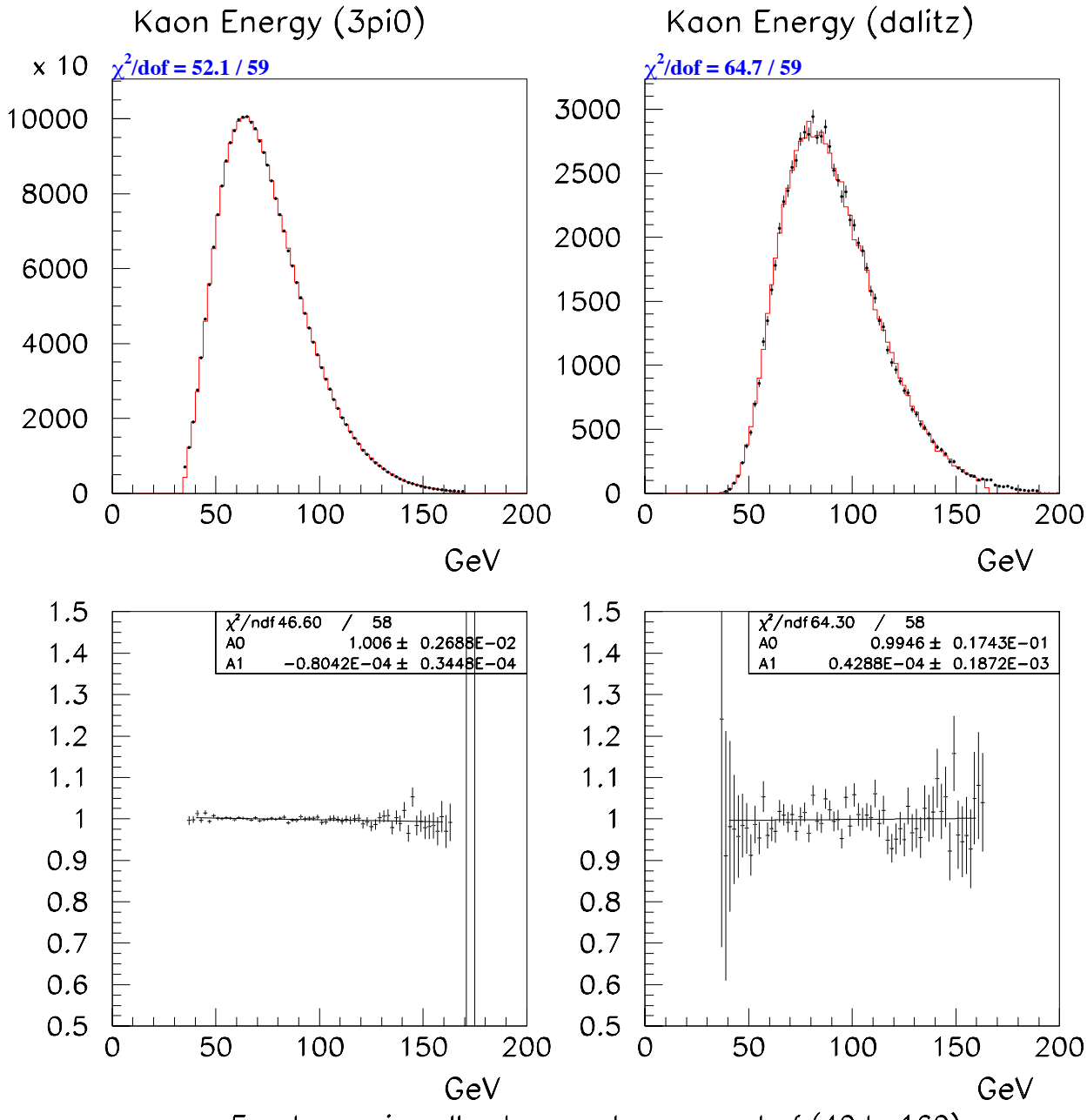




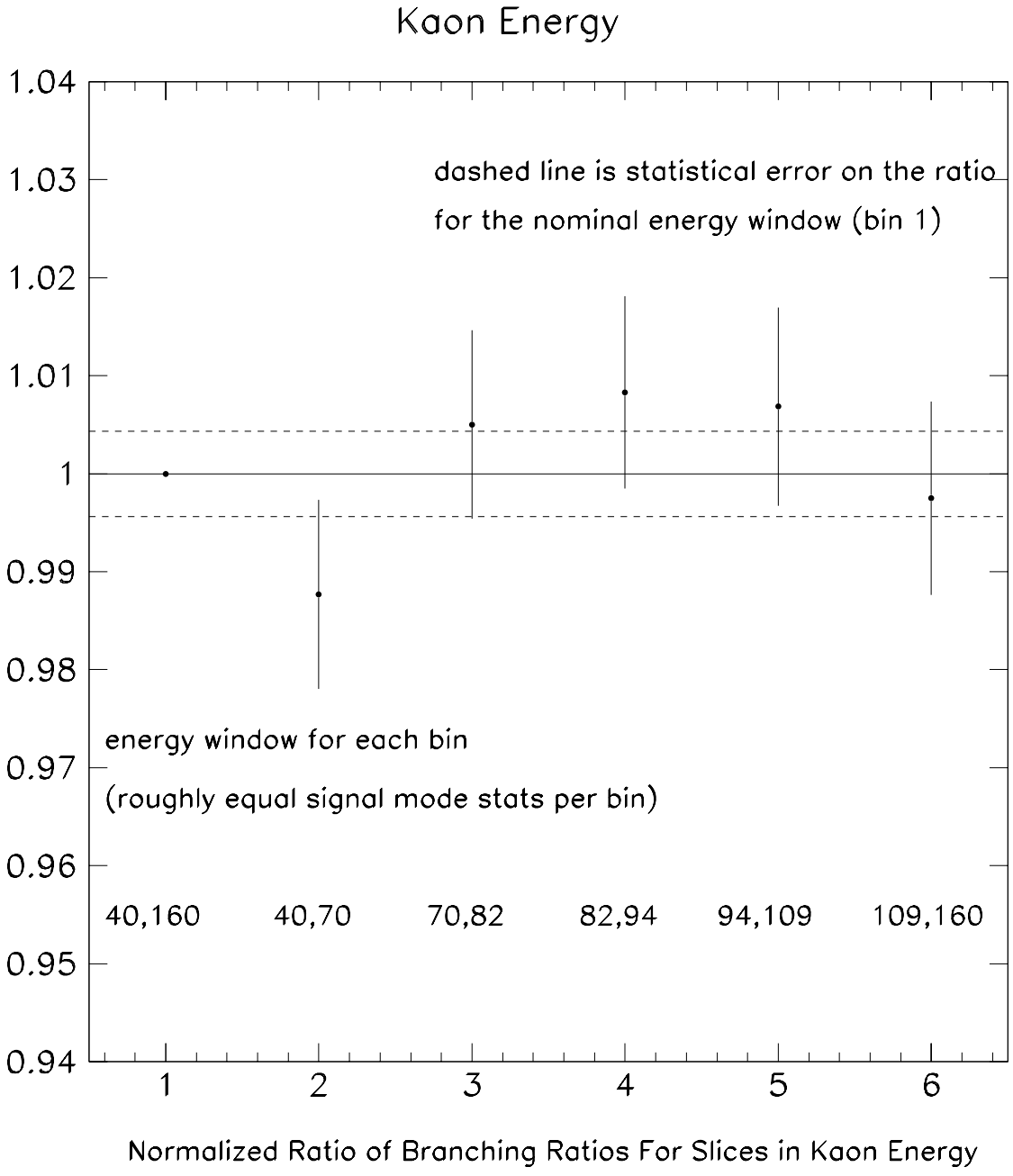


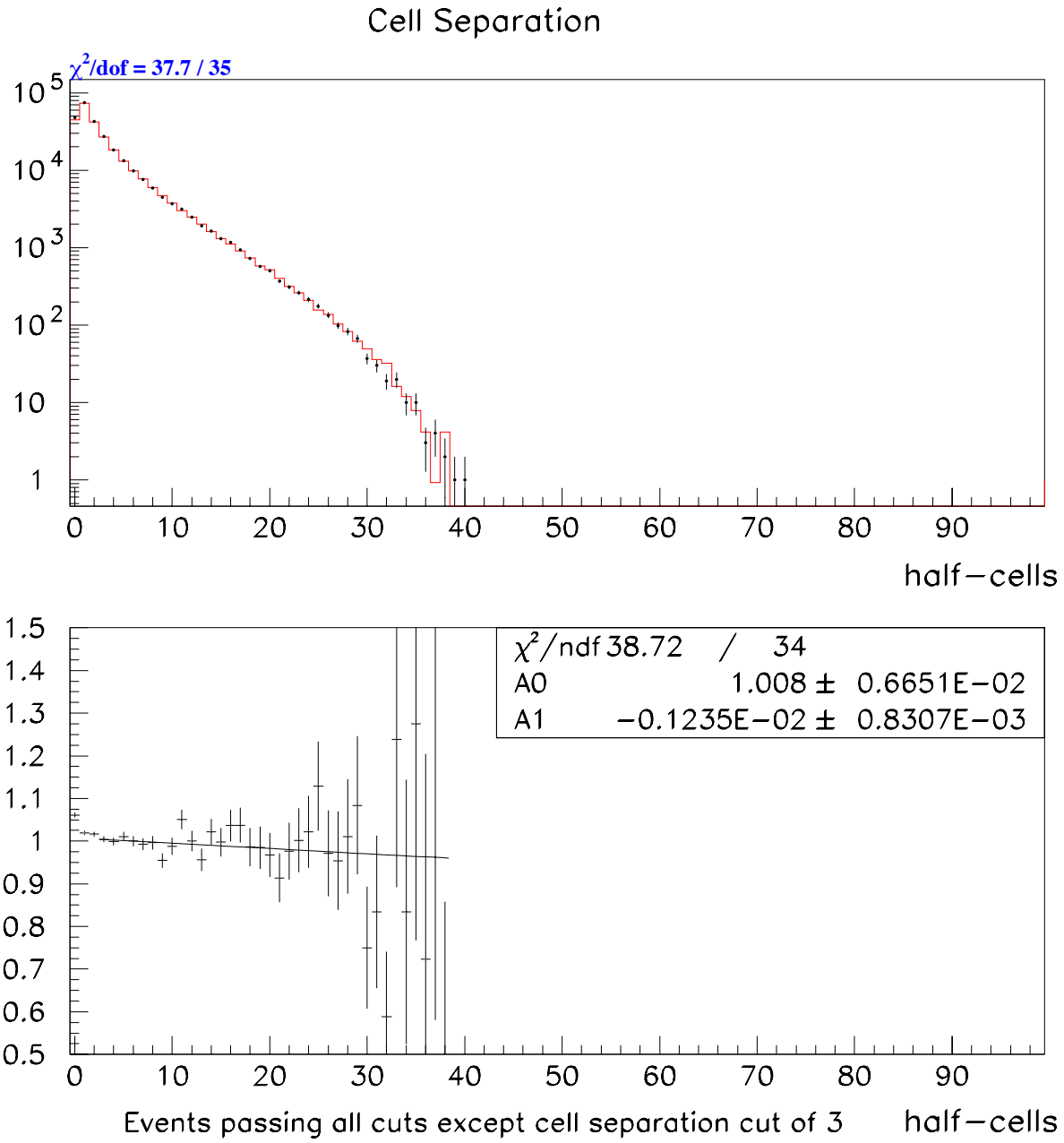
Events passing all cuts except z cut of (123 to 158)

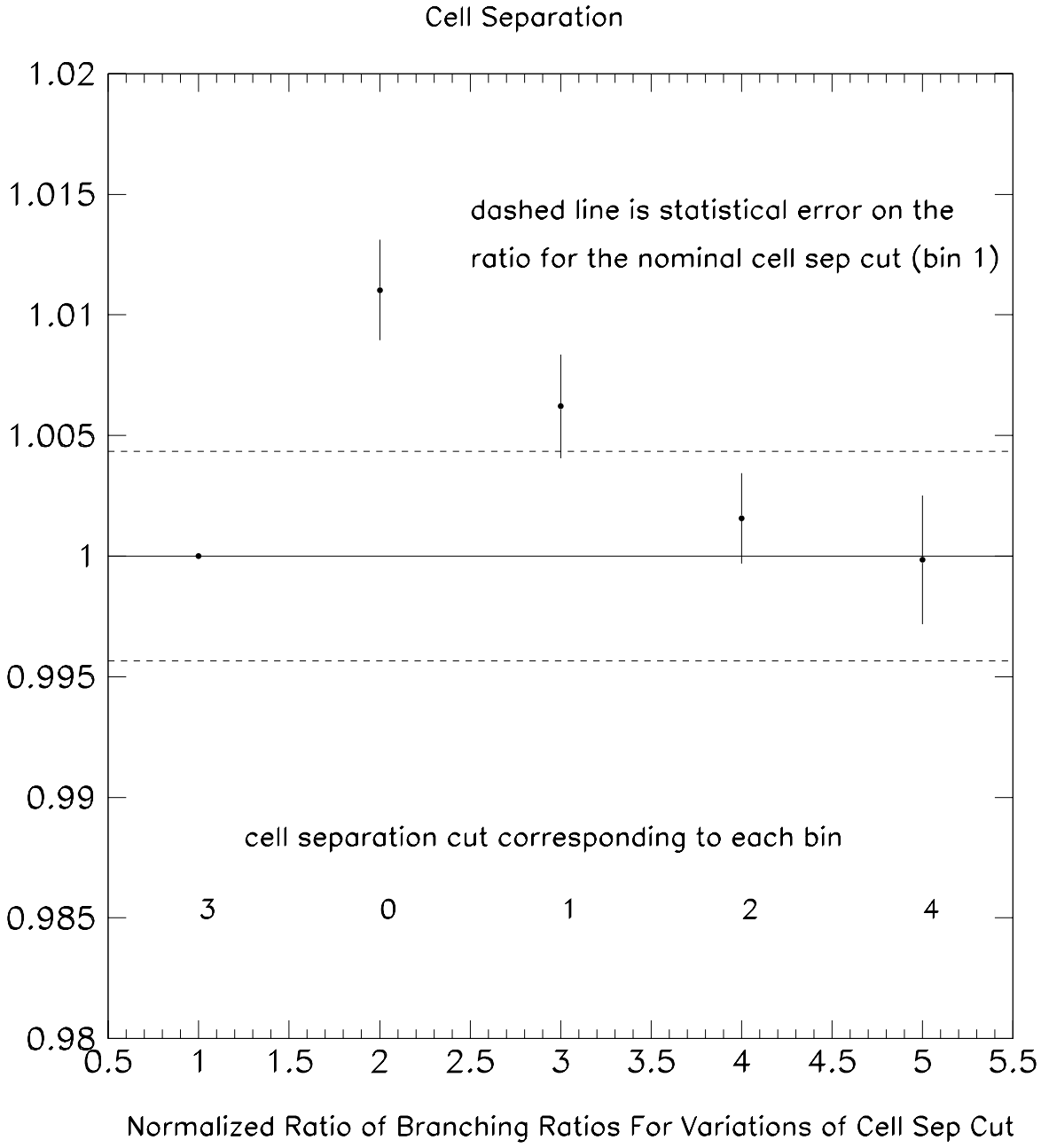

Kaon Z
1.1
1.08
1.06
1.04
1.02
1
0.98
0.96
0.94
dashed line is statistical error on the
ratio for the nominal z window (bin 1)
z window for each bin (roughly equal signal mode stats per bin)
123,158
123,126.5
126.5,130
130,134
134,139
139,158
1
2
3
4
5
6
Normalized Ratio of Branching Ratios For Slices in Kaon Z



Events passing all cuts except energy cut of (40 to 160)


Kaon Energy
1.04
1.03
1.02
1.01
1
0.99
0.98
0.97
0.96
0.95
0.94
dashed line is statistical error on the ratio
for the nominal energy window (bin 1)
energy window for each bin
(roughly equal signal mode stats per bin)
40,160
40,70
70,82
82,94
94,109
109,160
1
2
3
4
5
6
Normalized Ratio of Branching Ratios For Slices in Kaon Energy


Cell Separation
χ^2/dof = 37.7 / 35
10^5
10^4
10^3
10^2
10
1
0
10
20
30
40
50
60
70
80
90
half−cells
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
χ^2/ndf 38.72 / 34
A0 1.008 ± 0.6651E−02
A1 −0.1235E−02 ± 0.8307E−03
Events passing all cuts except cell separation cut of 3
half−cells


Cell Separation
1.02
1.015
1.01
1.005
1
0.995
0.99
0.985
0.98
dashed line is statistical error on the
ratio for the nominal cell sep cut (bin 1)
cell separation cut corresponding to each bin
3
0
1
2
4
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
Normalized Ratio of Branching Ratios For Variations of Cell Sep Cut

Systematics & Strategies: Trigger Efficiency

Run dalitz analysis on random accepts from trigger 6 (QKS tapes) and check that those events that reconstruct as dalitz decays show up in trigger 14.

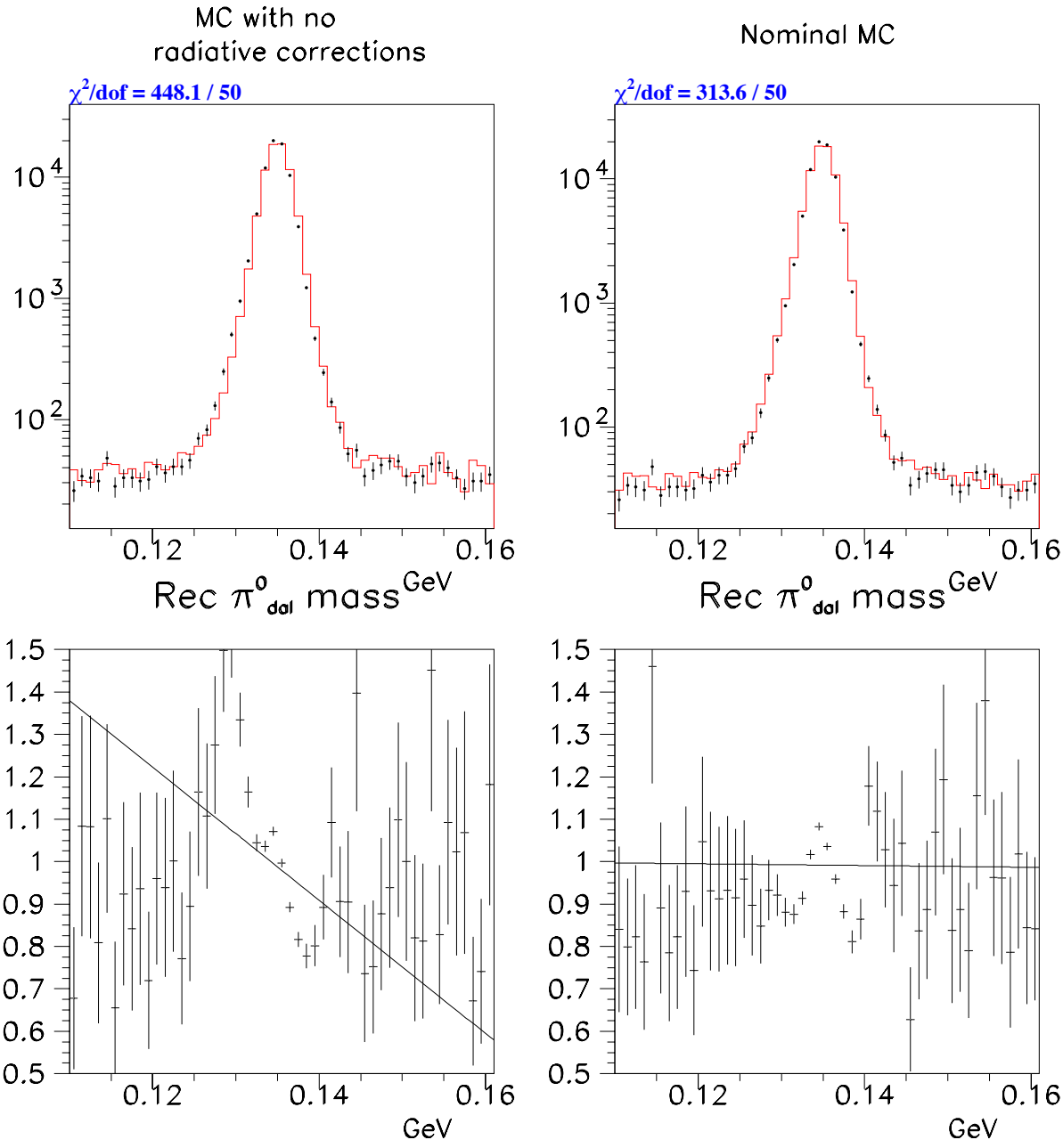
- Using nominal cuts, not many events
- First pass $\rightarrow$ inefficiency of 1/200
- Want to loosen cuts to improve statistics, but this requires dealing with some trigger verification issues

Systematics & Strategies: Radiative Corrections

First step: I generated signal MC with no radiative corrections to compare with my nominal MC.

The acceptance changes by ∼5%. However, several distributions show significant discrepancies when radiative corrections are neglected.

For example, the π^0_{dalitz} mass peak shifts by $\sim$ 20 sigma, so the acceptance uncertainty due to radiative corrections will be much less than 0.5%.


MC with no
radiative corrections
χ^2/dof = 448.1 / 50
10^4
10^3
10^2
0.12
0.14
0.16
Rec π^0_{dal} mass GeV
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.12
0.14
0.16
GeV
Nominal MC
χ^2/dof = 313.6 / 50
10^4
10^3
10^2
0.12
0.14
0.16
Rec π^0_{dal} mass GeV
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.12
0.14
0.16
GeV

Systematics & Strategies: Form Factor

First step: vary the form factor via the pi0_slope_param to see the effect on acceptance.

HOWEVER: dalitz parameters are never initialized in 832, so all my old MC was generated with no form factor.

Back to step zero: I fixed this in my MC code, and generated MC with nominal form factor (pi0_slope_param = $.032 \pm .004$). I compared the acceptance from old MC (presumably pi0_slope_param = 0) with new: change is less than 1%.

Acceptance is very insensitive to the form factor!

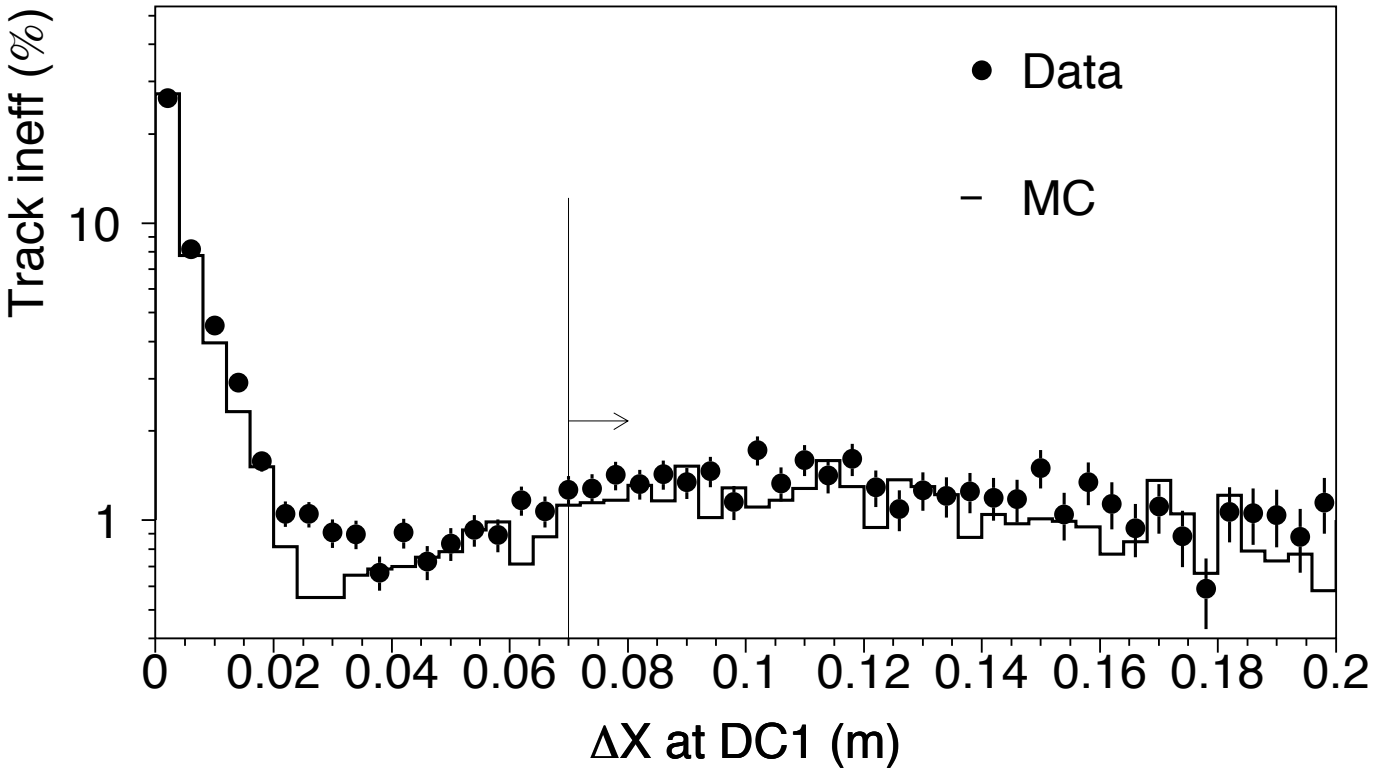
Next step: Generate MC with pi0_slope_param shifted by, say, one sigma, and see what the effect is.

Still need to think about whether we can/want to make a form factor measurement.

Note that radiative corrections study was done prior to finding this bug; it shouldn't matter much, but it will be redone with the nominal form factor.

Systematics & Strategies: Tracking Efficiency

Use the studies from V_{us}, which are valid when we apply a cellsep cut.



Plot from Branching Ratio paper from a study on tracking inefficiency as a function of track separation at DC1. Cell separation cut of 3 half-cells corresponds to ~ 2 cm.

Also, I am in the process of studying tracking efficiency as a function of intensity.

Systematics & Strategies: Background

Background is very small, but we need to study it. The main source is photon conversions.